Impact of the 1997/8 El Niño on highland malaria in Tanzania

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We compared the level of malaria infection experienced by children in 22 communities in an area of unstable transmission in the Usambara Mountains, Tanzania, immediately before and after one of the strongest recorded El Niño Southern Oscillation events. Although this El Niño resulted in 2.4 times more rainfall than normal, we found markedly less malaria than the preceding year.

The 1997/98 El Niño Southern Oscillation (ENSO) was one of the largest experienced this century and had catastrophic consequences in different parts of the world[1]. In the East African Highlands ENSO events result in exceptionally heavy rainfall and elevated temperature[2]. Consequently, in these highlands, where malaria transmission is absent or unstable, such a severe El Niño was expected to increase mosquito production and precipitate malaria epidemics in the region[3]. We were in the unique and serendipitous position of having conducted malaria surveys in communities in the Usambara Mountains in north-eastern Tanzania immediately before the 1997/8 El Niño. Thus in order to measure the impact of this major climate event, we surveyed the same villages the following year, after the ENSO event.

The West Usambara mountains cover an area of approximately 2,500km^2 and rise sharply from the surrounding plains, between 200-500m, to the highest peak around 2,000m. Villages were selected from 12 equal sectors radiating from the centre of the mountains. 22 highland villages between 850-2000m altitude were surveyed in August 1997 and in early September 1998, after the usual period of peak transmission in the lowlands. After obtaining informed consent, a cluster sample of approximately 80 children aged between 2-9 years old were examined in each village for the presence of an enlarged spleen. In addition, a finger-prick sample of blood was taken and examined by microscopy for the presence of malaria parasites.

Annual rainfall for Kilimo Station, Lushoto (4°47'S, 38°17'E), in the south west of the mountains, during the El Niño year in 1997 was unprecedented, with 2,402mm recorded compared with the 1961-90 mean of 1,062mm (95% CIs = 996-1,129mm). Most of the heavy rains fell in October and November 1997 (Figure). There was little evidence to suggest that temperatures changed appreciably during the El Niño. Temperatures recorded at 5 villages situated between 300-1700m recorded a median rise in temperature of 0.2°C (range = -0.5 to1.0°C) in November 1997, at the height of the El Niño, compared with the previous year.

Overall there was a significantly lower prevalence of parasitaemia and splenomegaly in children after the El Niño than before (Figure; median parasitaemia pre-ENSO = 19.6% *vs* 11.3% post-ENSO, Wilcoxon's signed rank test; $z = -2.45$, $p = 0.014$; median spleen rate pre-ENSO = 16.1% *vs* 4.0% post-ENSO, $z = -2.31$, $p = 0.021$). These rates were not age-standardised because the rate of infection was similar in all age groups. In contrast to most settlements there were 3 communities (F, J & K) which experienced higher rates of infection and splenomegaly after the El Niño than before (Figure). Two of these (F & K) were situated in the same broad valley, which may have retained large areas of standing water, ideal breeding sites for *Anopheles gambiae* s.l., the main highland vector. The cause of the outbreak in village J was not known.

The general decline in infection associated with the 1997/8 El Niño was contrary to our expectations. Heavy rainfall may have flushed out anopheline mosquitoes from their breeding sites, resulting in fewer adult mosquitoes and lower exposure to malaria parasites. Although no systematic entomological surveys were carried out, anopheline larvae were extremely difficult to find in the lowlands during the El Niño, in marked contrast to other years (C. Maxwell personal communication).

There is an increasing body of literature suggesting that weather associated with El Ni™o events can drive epidemics[4]. Indeed, heavy rains associated with the 1997/8 El Ni™o resulted in increased malaria in the south-western Highlands in Uganda[5]. Here we report the opposite effect, where high rainfall associated with the same El Niño event led to a general reduction in malaria in the Tanzanian Highlands. This study illustrates how difficult it is to use simple El Niño episodes to evaluate malaria outbreaks in the African highlands, particularly as there can be large variations in weather from one ENSO event to the next. Because of this variability, we strongly encourage scientists studying weather-disease dynamics to investigate the impact of actual weather elements, rather than using El Niño phenomena alone. It is also important to analyse longer series of data, rather than just two years, as we have done in the present paper. The large temporal and spatial variability in weather from one El Niño event to the next and the often considerable ecological variation which may exist within a region requires us to take a more sophisticated look at infectious disease-environmental relationships.

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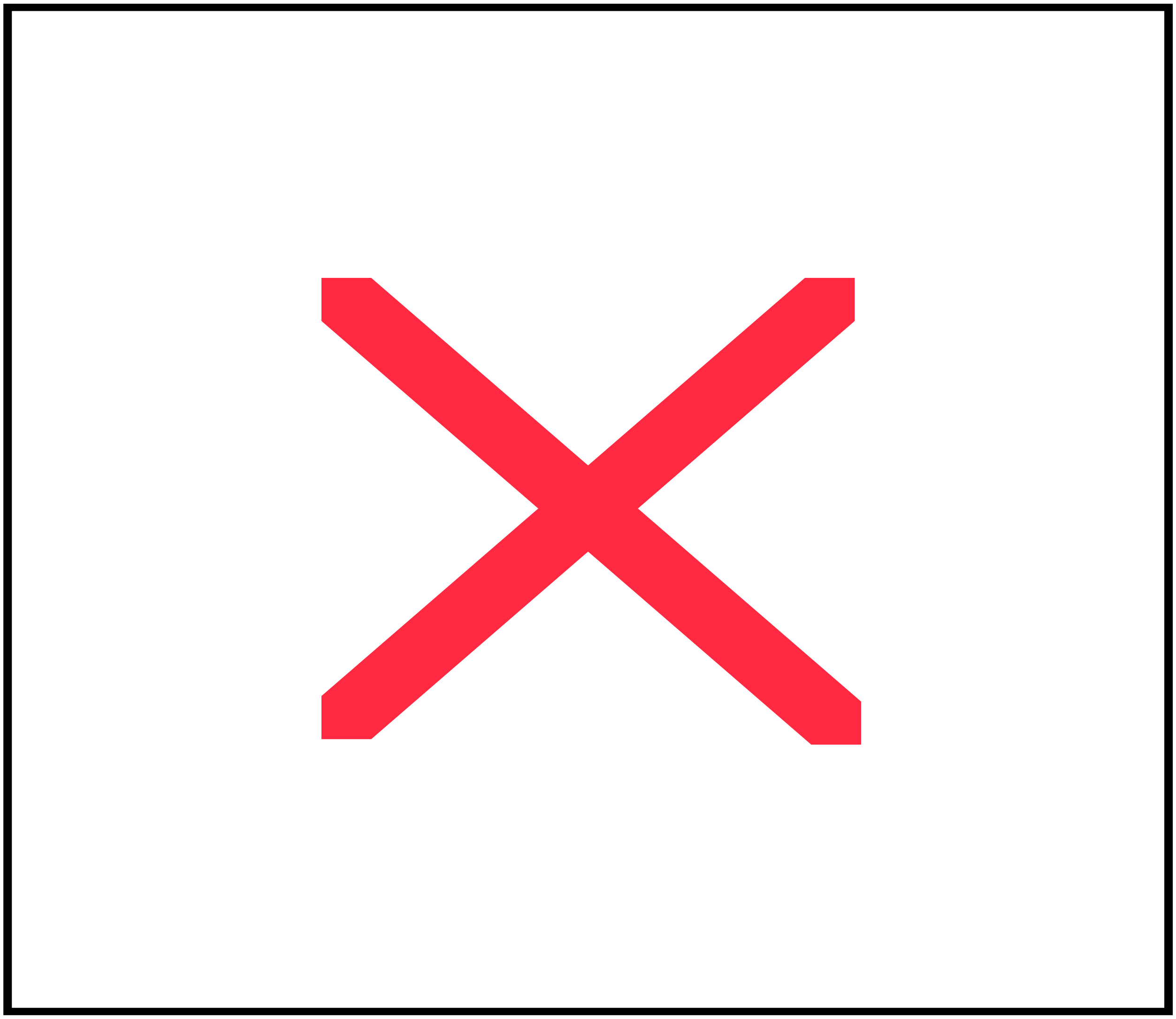
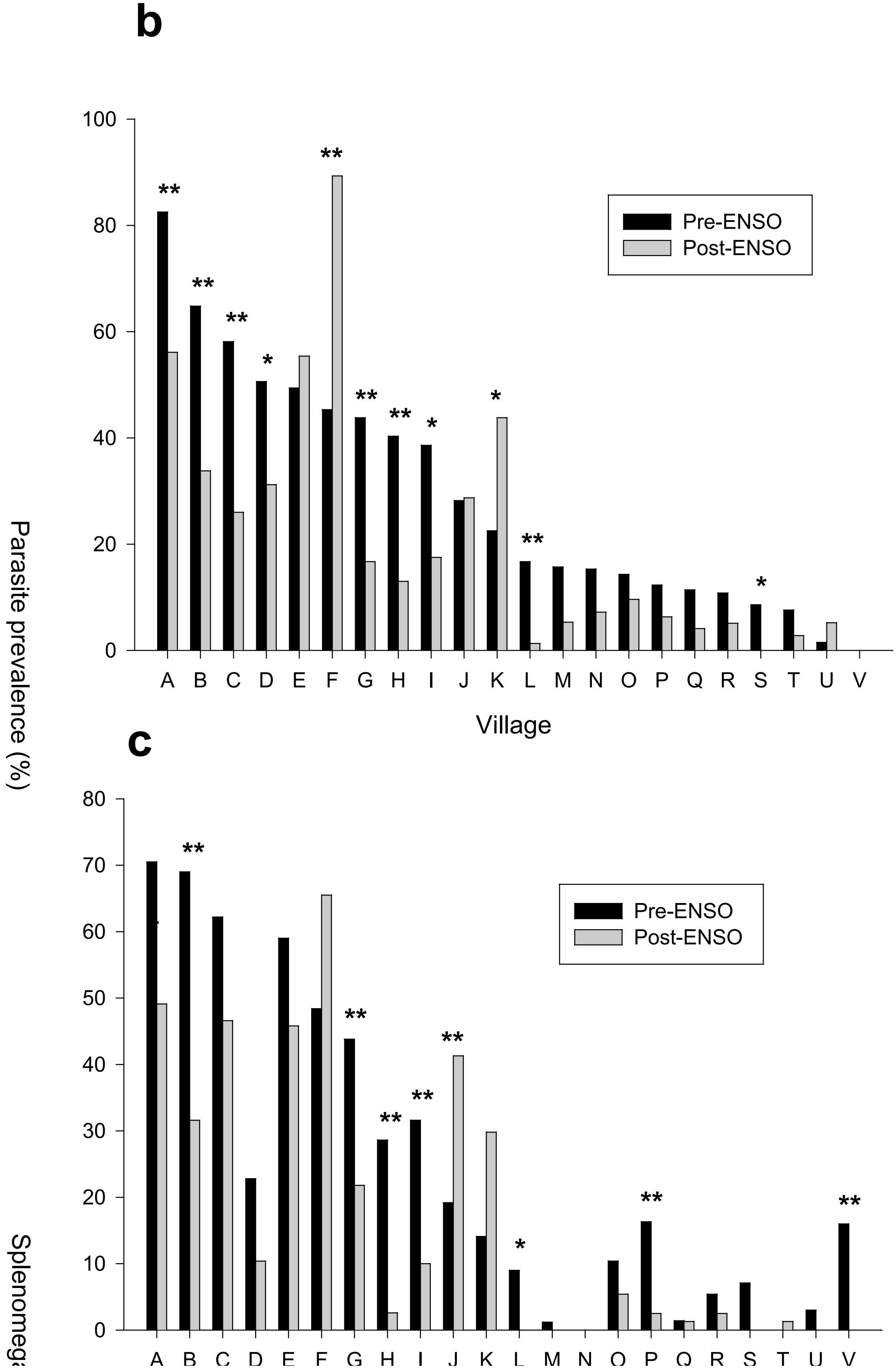
Figure Legend:

Figure: **a Rainfall associated with ENSO.** Monthly anomalies are related to the monthly means for the standard period, 1961-90**, b Parasite prevalence rates, c Splenomegaly prevalence rates,** where A = Msasa, B = Ungo, C = Mlesa, D = Makwele, E = Bagamoyo, F = Ubiri, G = Mbwei, H = Galambo, I = Ngazi, J = Ngua, K = Mshizii, L = Mgwashi, M = Mabugai, N = Viti, O = Ngwelo, P = Balangai, Q = Mtae, R = Mbelei, S = Mtai, U = Milungui and V = Longoi, *** =** P <0.05, ** = P<0.001 with comparisons made between years.





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